DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 114

A PORTABLE CUBIC-FOOT STANDARD FOR GAS

BY

M. H. STILLMAN, Assistant Physicist
Bureau of Standards

ISSUED JANUARY 28, 1919

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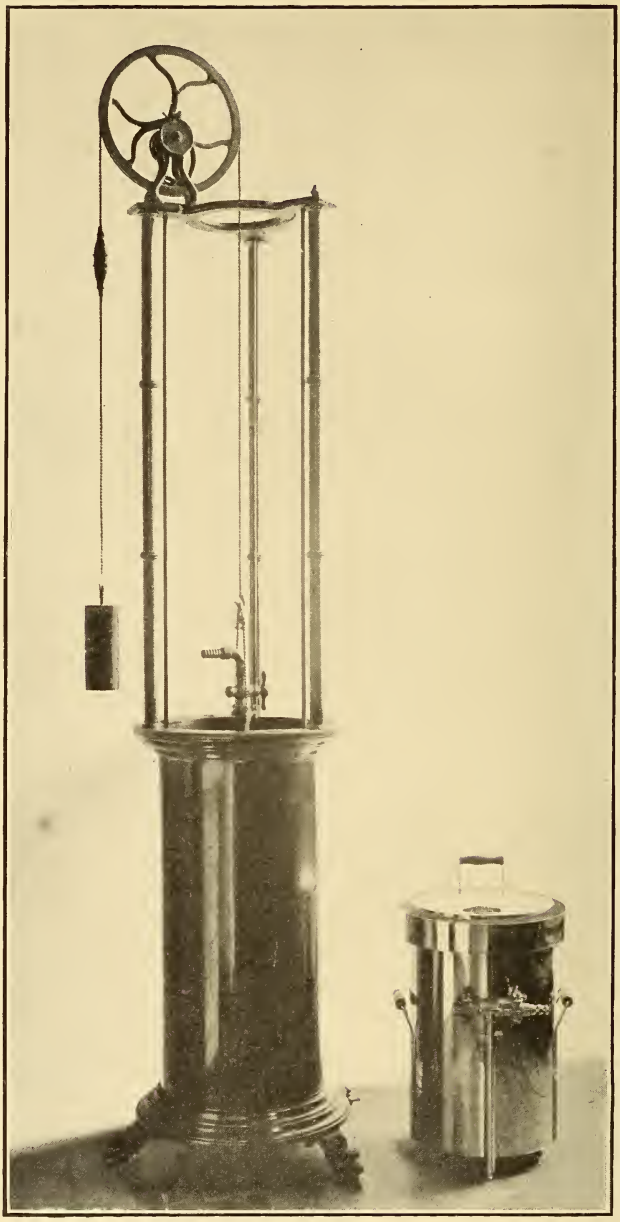

FIG. 1.—*Cubic-foot apparatus*

The new cubic-foot standard is shown at the right; at the left is shown one of the most compact types of cubic-foot bottles commonly in use at the present time

A PORTABLE CUBIC-FOOT STANDARD FOR GAS

By M. H. Stillman

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I. INTRODUCTION

The subject of this paper is a new type of volume standard for measuring gas which has been found to possess decided advantages as a cubic-foot standard over the apparatus of this class largely in use at the present time.[1]

While the portability, accuracy, and ease of operation of this device adapt it especially to that class of work in which an inspector is required to make tests of gas-meter testing equipment distributed over a comparatively large territory, it has also been successfully used for other purposes in which the delivery of a comparatively small volume of gas with a high degree of accuracy was required.

II. DESCRIPTION OF STANDARD

In Fig. 1, at the right, is shown a view of the new cubic-foot standard. It is about 25 inches high overall, and, in order to give an idea of its relative size, a cubic-foot bottle apparatus of

[1] A patent (No. 1 234 505) on this apparatus was granted to the author on July 24, 1917. This was dedicated to the public in the following words of the specification: "The invention herein described and claimed may be used by the Government of the United States, or by any of its officers or employees in the prosecution of work for the United States, or by any person in the United States, without payment of any royalty thereon."

Copies of this patent may be obtained for 5 cents each by making application to the Commissioner of Patents, Washington, D. C.

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one of the more compact types at present in use is shown at the left. Fig. 2 is a vertical cross section through the axis of the apparatus, and Fig. 3 is a horizontal cross section at line *III–III* of Fig. 2.

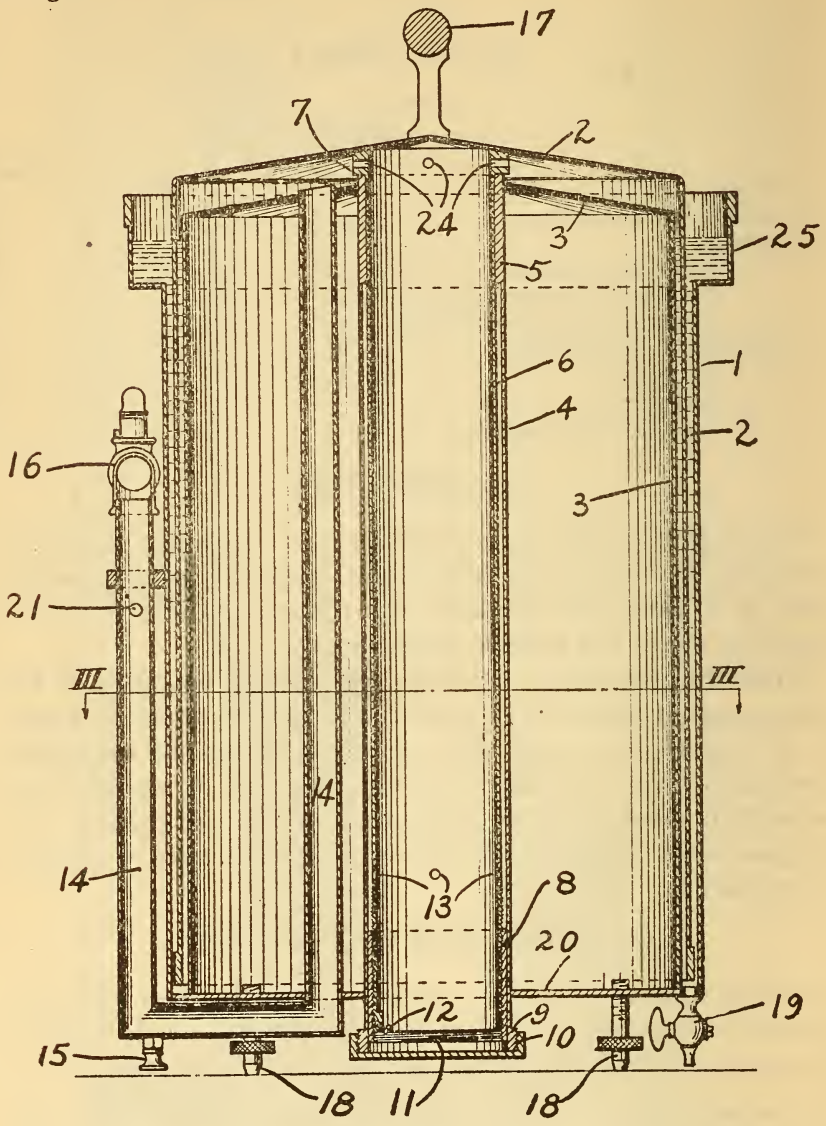

FIG. 2.—*Vertical cross section through cubic-foot bottle apparatus*

Referring to Figs. 2 and 3, *1* and *3* are coaxial cylinders, the annular space between them being closed at the bottom by the outer portion of the base plate *20*. This constitutes an annular tank in which the cylinder *2*, closed at the top as shown and

hereafter referred to as the bell, may be moved up and down, guided by the sliding mechanism at the axis of the apparatus. The inner cylinder *3* is also closed at the top and will be hereafter referred to as the core. The clearance space between the sides of the core and bell is made as small as is consistent with freedom of motion in order to minimize the changes in the volume of the sealing liquid within this space due to changes in the gas pressure within the bell. This results in rendering negligible the errors due to the small pressure changes that ordinarily occur. The

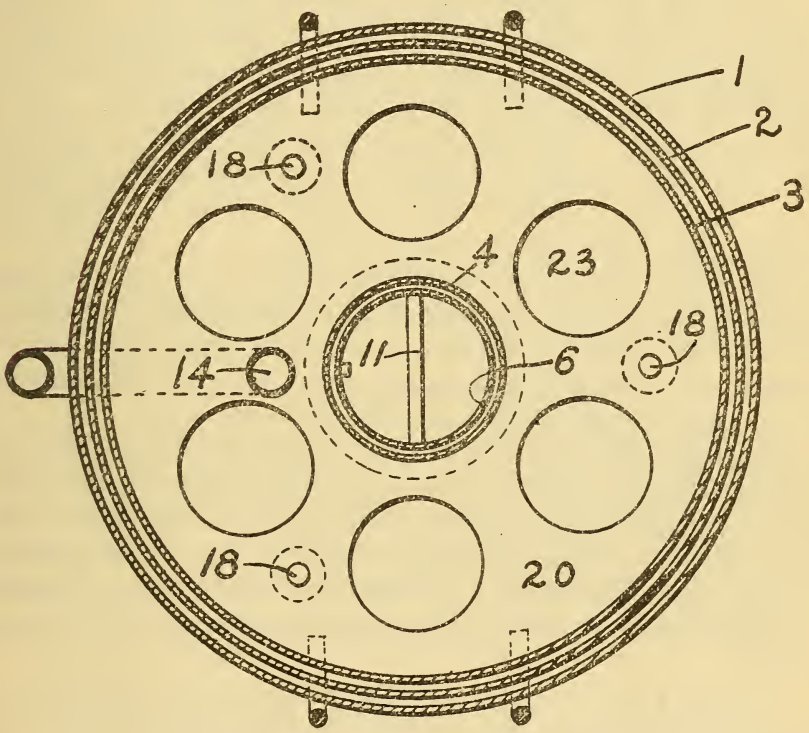

FIG. 3.—*Horizontal cross section through cubic-foot bottle apparatus*

diameter of the top of the outer cylinder *1* is enlarged to form a reservoir *25* of such capacity that the raising and lowering of the bell will not cause an excessive change in the height of the sealing liquid.

The guiding mechanism referred to above consists, primarily, of two telescoping tubes *4* and *6*, the inner tube *6* being securely fastened to the inside of the top of the bell, and consequently, as the bell is raised and lowered, sliding up and down within the stationary tube *4*, which is secured gas tight to the core and the base plate *20*. The interior of the upper end of the outside

guide tube is provided with a thickened portion or ring *5*, which is of such a thickness as to closely fit around the inside tube. The exterior of the lower end of the inside tube is provided with a screw thread to which is screwed, by means of a handle *11*, a ring or collar *8*, of such a thickness as to fit closely the inside surface of the outside tube. There is thus provided for the bell a guiding mechanism permitting very little lateral motion. It is evident that when the bell is raised by means of the handle *17* the upward motion will be limited by the collar *8* coming in contact with the shoulder formed by the collar *5*. It is also evident that the height to which the bell can be raised may be regulated by screwing the collar *8* up or down upon the inner tube. This collar when adjusted is fixed to the inside tube by means of the set screw *12*. The lowest position of the bell is established by the collar *7*, which is fastened to the bell and inside guide tube, coming in contact with the upper end of the outer stationary guide tube and its attached collar.

The wall of the lower end of the outside tube *4* is thickened and provided with an external screw thread to which is screwed the cap *10*, making therewith a gas-tight joint. In order to connect the interior of this guiding mechanism with the interior of the bell, two sets of holes *24* and *13* are provided.

To connect the interior of the bell with the free air or with any volume of gas, the tube *14* passes gas tight through the top of the core, down through the bottom *20*, and up to the valves *16*. The two valves *16*, which are clearly shown in Fig. 1, may advantageously be replaced by one three-way valve. To the opening *21* a manometer or other pressure-measuring device may be connected.

A stopcock *19* is connected to the bottom of the annular tank in order to provide a means of removing the sealing liquid which normally fills the tank up to approximately the height shown in Fig. 2.

The gas conductor *14* is provided with a drain cock *15* which is used to remove any sealing or other liquid which may accidentally enter the conductor.

Three screw feet are inserted into the bottom in order that the entire apparatus may easily be leveled.

A number of large holes *23*, Fig. 3, are placed in the bottom *20* in order to decrease the weight of the apparatus and to allow the air of the room to get within the core and thereby more quickly equalize the temperatures of the apparatus and the room.

While the instruments so far constructed have been either of brass or copper, aluminum could well have been utilized to a very large extent and the weight thereby materially reduced.

Only a little more than 1 gallon of sealing liquid is required by each instrument.

III. OPERATION

Briefly stated the method of operation is as follows: The annular tank is first filled with water or preferably an oil of small vapor pressure and small viscosity. The raising of the bell *2* to its upper limit by means of the handle *17* draws into the interior of the bell through the valve *16* and tube *14* a definite volume of gas. The magnitude of this volume depends for a given apparatus upon the distance the bell can be raised, which is the distance between the stops *5* and *8*. If the bell is then lowered to its initial position, it is obvious that the same definite volume of gas will be expelled.

The method of calibrating and adjusting the apparatus to deliver 1 cubic foot with the required accuracy will be described later; for the present it will be assumed that this adjustment has been made.

1. CALIBRATION OF PROVERS

The manner of using the apparatus to calibrate meter provers is so simple that those who have used the ordinary cubic-foot bottles would be able to use it successfully without further explanation. Use of the apparatus has, however, indicated certain details which should be observed if all the advantages inherent in this form of standard are to be realized. In order to aid in the discussion of these the following outline of procedure, which has been successfully used, is given:

1. Open one of the valves *16* to the air of the room and fill the annular tank with sealing liquid (preferably a proper oil) up to within about 1 inch of the top of the tank.

2. Connect one of the outlets *16* to the prover by means of a rubber tube.

3. Open all valves between prover and cubic-foot apparatus.

4. Test apparatus and connections for leaks.

5. Make necessary temperature adjustments.

6. Fill prover with air at normal prover pressure (usually 1½ inches of water) and adjust so that reading is zero.

7. Raise bell of standard from lowest position to highest position, thereby withdrawing 1 cubic foot of air from prover, read

prover, and record reading. (It will be necessary to keep the hand on the handle of the bell in order to maintain the bell in its highest position while taking this reading.)

8. Reintroduce into prover the cubic foot of air from standard by pushing bell down to lowest position and again make and record prover reading. Operations 7 and 8 effect two determinations of the interval 0–1 of the prover. Repeat these operations a sufficient number of times to determine the true volume of the interval 0–1 with the required accuracy.

9. With the bell of cubic-foot apparatus in lowest position allow 1 cubic foot of air to escape from the prover into the room and calibrate the next interval 1–2 of the prover in exactly the same manner as the interval 0–1 was calibrated.

10. Calibrate the other intervals in the same manner.

As is generally true when accurate comparisons of volume are to be made with air or gas as the medium of comparison, care must be taken to make proper allowance for difference in temperature and vapor content of the air in standard and prover. Generally the most satisfactory and practicable procedure is to have the temperature of all parts of the system involved in the comparison practically the same. If, as is advocated, a suitable oil is used as a sealing liquid in the standard, changes of temperature due to evaporation from the outside of the bell are practically zero. Also, because of the construction of the standard and the small amount of sealing liquid required by it, the temperature of the standard will be maintained at very nearly that of the room unless the room temperature varies rapidly. The advantages of this are evident. If, as advised under 6 of the above outline of procedure, the test is started with the bell of the prover full of air, the bell should remain in its highest position for some time before the test is started, allowing its surface to become dry and its interior to become saturated with water vapor (assuming that water is being used as a sealing liquid in the prover). By so doing the test may be conducted with practically a dry bell, the maximum wetted surface exposed to the air of the room at any time being that corresponding to 1 cubic foot of its volume, the average exposed wetted surface being only about one-half of this maximum.

In order to insure that the air in prover and cubic-foot apparatus is thorougly mixed and saturated with water vapor, it is well to transfer a quantity of air back and forth between prover and

standard a number of times by raising and lowering the bell of the standard.

A good indication that the conditions are satisfactory for the commencement of the test is obtained by first noting the reading of the prover and then after interchanging air between standard and prover a few times noting the reading again. If the reading of the prover has not changed appreciably, it may be safely assumed that no serious leak exists and that the conditions of the air in prover and standard are, at least, temporarily stable.

It is very desirable to test the prover with the same air pressure in the bell and the same quantity of sealing liquid in the tank as obtain while the prover is being used to test meters. If this is not done, it is evident that the portion of the prover bell corresponding to a given interval on the scale while the prover is being tested will, in general, not be identical with the portion corresponding to the same interval while the prover is being used to test meters.[2] The cubic-foot standard under discussion is unusually well adapted to take advantage of this fact since its operation at ordinary prover pressures is the same as at atmospheric pressure.

In operating the standard, care must be taken not to raise or lower the bell too quickly. If it is raised too quickly, the air pressure inside the bell may be so much reduced that the sealing liquid will be drawn up over the core and into the gas conductor, or if at the commencement of the down stroke the bell is pushed down too rapidly, it will force the air out from the bottom of the bell. Of course, by increasing the size of the gas conductor or making it extend higher inside of the bell, the speed of the operation of the instrument may be greatly increased; but it has been found that even with the proportions shown in the drawing the apparatus may be easily and successfully operated considerably faster than the ordinary cubic-foot bottle.

There is given below a copy of the data sheet of the calibration of a 5-cubic-foot prover by the new standard. The prover bell was of painted sheet iron and was protected from the direct action of the air of the room by a stationary metal cover which was supported upon the rim of the prover tank. The sealing liquid used in both prover and cubic-foot standard was a thin oil which has been found very satisfactory.[3] The table shows the

[2] If the prover bell were of absolutely uniform diameter throughout that portion of its length exposed to the sealing liquid, this would be unimportant; but since variations do frequently occur in manufacture and through accidental denting, it is very desirable, as stated, to adopt a method of test that will avoid incorrect results due to such variations.

[3] The oil used as a sealing liquid is known as P. I. Meter Oil. It has the following physical characteristics: Flash point 65° C; fire point 90° C; viscosity 46 seconds at 100° F (Saybolt scale).

close agreement of successive determinations of the same interval that may be expected when proper precautions are taken. When water is used as a sealing liquid and the unsaturated air of the room is allowed to circulate freely about the bell of the prover, the results will be less accurate and the variations of successive determinations will be greater.

Data of Calibration of 5-Cubic-Foot Meter Prover

Interval on prover in cubic feet	Reading of prover scale		Volume of discharge indicated by prover	Temperature of cubic-foot standard	Temperature of prover	Temperature of air of room	Actual discharge for 1 cubic foot indicated by prover
	Before discharge	After discharge					
			Cubic feet	° C	° C	° C	Cubic feet
	0.000	0.998	0.998	21.5	21.5	22.0	.....
	.000	.997	997	.....	.....	.....	.....
0–1 (1.30 p. m.)	.000	.9975	.9975	.....	.....	.....	.....
Mean	.....	.....	9975	.....	.....	.....	1.002
	1.000	1.997	997	.....	.....	.....	.....
	.999	1.996	997	.....	.....	.....	.....
1–2	.999	1.996	.997	.....	.....	.....	.....
Mean	.....	.....	.997	.....	.....	.....	1.003
	2.000	3.000	1.000	.....	.....	.....	.....
	2.000	3.000	1.000	.....	.....	.....	.....
2–3	1.999	2.999	1.000	.....	.....	.....	.....
Mean	.....	.....	1.000	.....	.....	.....	1.000
	2.998	3.996	.998	.....	.....	.....	.....
	2.998	3.996	.998	.....	.....	.....	.....
3–4	2.998	3.996	.998	.....	.....	.....	.....
Mean	.....	.....	.998	.....	.....	.....	1.002
	4.000	4.993	.993	.....	.....	.....	.....
	4.000	4.993	.993	.....	.....	.....	.....
4–5 (2.10 p. m.)	4.000	4.9925	.9925	21.9	21.9	22.1	.....
Mean	.....	.....	.9928	.....	.....	.....	1.007

Practically all of the methods of calibrating a prover at present in use, including that just described, involve the introduction into or withdrawal from the prover of a whole cubic foot of air, the only scale reading being that of the prover. As is well known, it is not always easy to read these scales accurately, say to one one-thousandth cubic foot, because of the length of the smallest interval (sometimes one-tenth cubic foot) and also because of the considerable width of the division marks. Some provers are provided with verniers by means of which the scales may be read to one one-thousandth of a cubic foot, but this is not common.

In order to avoid errors in reading due to the width of the graduations, the writer has found that the practice of reading either the top edges of all of the graduations of a given scale or the bottom edges of all the graduations is effective if the edges are straight and clearly defined.

2. USE OF NEW AUXILIARY METER-PROVER SCALE

For reading the prover scale with the accuracy desired in prover calibrations, the auxiliary scale described below has been used successfully for some time. While it was designed particularly for use in connection with the herein-described cubic-foot standard, it will be obvious that it is equally applicable where a prover is being calibrated by any form of cubic-foot standard.

As shown in Fig. 4, the auxiliary scale is simply a stationary scale *B* divided into divisions of such length as to correspond to one one-hundredth cubic foot on the prover scale *C*, and numbered as shown. This scale is then firmly mounted in front of and close to the prover scale. In reading the prover, the foot

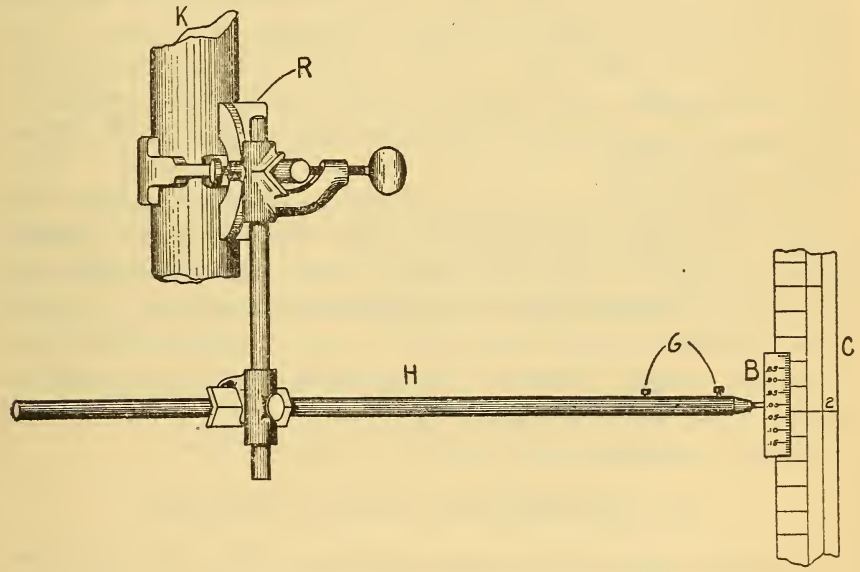

FIG. 4.—*Auxiliary meter-prover scale.*

division on the regular prover scale is considered as the index which moves under the stationary auxiliary scale. Thus the reading of the prover as illustrated in Fig. 4 is 2.026 cubic feet.

A convenient form of clamp permitting the easy adjustment of the auxiliary scale to the prover is also shown in Fig. 4 fixed to a column *K* of the prover. Four thumbscrews (not shown) on the right jaw *R* of the column clamp permit the adjustment of the clamp to the column whether this be of uniform or variable diameter. Inasmuch as provers of different diameters require scales of different sizes, provision is made for easily interchanging scales and firmly fastening them to the rod *H* by means of the thumbscrews *G*.

This scale makes it practicable to read the ordinary 5-cubic-foot prover to one one-thousandth cubic foot a degree of accuracy which is commensurate with the constancy of volume of gas in the prover bell which it is practicable to maintain for a short time under good laboratory conditions.

3. ADJUSTMENT OF CUBIC-FOOT STANDARD

The adjustment of the new cubic-foot standard to take in and deliver 1 cubic foot of air or other gas with a high degree of accuracy is easily made by making use of an accurately calibrated cubic-foot bottle.

The method consists of so adjusting the capacity of the new standard that upon discharging into it 1 cubic foot of air from the standardized cubic-foot bottle no change of pressure in the new standard takes place. As is evident from the description of the apparatus, the capacity of the standard is increased or decreased by screwing the adjustable guide and stop *8*, respectively, down or up.

The apparatus is well adapted to being officially adjusted and sealed. Sealing is accomplished either by sealing the adjustable lower guide *8* to the inner guide tube, thus preventing relative motion between the two, or by sealing the cap *10* to the outer guide tube in such a way that it can not be removed without breaking the seal. Moreover, with the bell in its lowest position, which it normally occupies except when a test is being made, it is almost completely protected from accidental injury.

IV. ADVANTAGES OF NEW STANDARD

Use of the cubic-foot standard described in this paper has shown it to be practicable and to possess to a marked degree the following advantages:

1. PORTABILITY

The apparatus is so compact and light that it can be carried about by one man. By providing it with a case it can safely be checked as baggage or shipped by express.

2. ACCURACY

While in itself this apparatus is not more accurate than the regulation cubic-foot bottle so commonly in use, yet it is believed that with the ordinary care that it is practicable to exercise in routine prover testing, the new apparatus will generally give more

accurate results than the former, because (1) it is practicable to use oil as a sealing liquid, since the small amount (little more than 1 gallon) can be easily carried with the apparatus or kept at each prover station. The oil does not evaporate from the surface of the bell to an appreciable extent and so introduce errors due to cooling and change of vapor pressure within the bell. (2) As explained above, it is very convenient to test the prover under the same conditions as regards pressure in the prover bell and quantity of sealing liquid in the tank as obtain during routine meter testing. (3) The transfer of air between prover and standard is accomplished very quickly, thus reducing variations in temperature and vapor pressure within the prover and standard during the test of a given interval.

3. CONVENIENCE AND RAPIDITY

Setting up the new standard for a test consists simply in removing it from the case and pouring the necessary quantity of oil (or other sealing liquid) into the tank. This requires only a few moments. After completing the test of one prover the standard may be easily moved to the next by one man without removing the sealing liquid. The operation of calibration itself is rapid; considerably faster than is practicable with the ordinary cubic-foot bottle.

WASHINGTON, January 1, 1918.